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Project Title: Remediative Sediment Cap for Hydrocarbon Spills

Project Category: Contaminated Sediments

Rank by Organization (if applicable): 0

Total Funding Requested ($): 239,930 **Project Duration:** 2 Years

Abstract:

The goal of this project is to evaluate and design a system to cap and remediate sediments contaminated with hydrocarbons in the St. Louis River Area of Concern (Duluth, MN harbor) through increasing the depth of the aerated sediment zone. Submerged bubblers, surface aerators, or surface pumps may be an appropriate technology for implementation at several locations in this waterbody for water quality restoration and long-term protection. This technique improves water quality by increasing the dissolved oxygen (DO) concentration in the sediments by two means: a) increasing DO in the water column; and b) increasing the rate of transfer of DO across the interface. Together, these will result in an increased depth of the aerated sediment zone. The increased DO may serve to both cap and remediate the sediment. Degradation of polycyclic aromatic hydrocarbons by microbes is an aerobic process and could be stimulated by increased DO levels in the near surface sediments. In addition, bioturbation and bioirrigation will be significantly reduced. The common aquatic worm, Tubifex tubifex, for example, will not enter the water column unless it requires oxygen. The same could be said for most other bioirrigators and bioturbators.The potential of this relatively simple technique, when applied in an elegant manner, is therefore substantial for the remediation of sediments contaminated with hydrocarbons.

Geographic Areas Affected by the Project

States:

- ☐ Illinois
- ☐ Indiana
- ☐ Michigan
- ☒ Minnesota
- ☐ New York
- ☐ Pennsylvania
- ☐ Wisconsin
- ☐ Ohio

Lakes:

- ☒ Superior
- ☐ Huron
- ☐ Michigan
- ☐ Erie
- ☐ Ontario
- ☐ All Lakes

Geographic Initiatives:

☐ Greater Chicago ☐ NE Ohio ☐ NW Indiana ☐ SE Michigan ☐ Lake St. Clair

Primary Affected Area of Concern: St. Louis River, MN

Other Affected Areas of Concern: Results of this study (i.e. design criteria) may have beneficial use at other AOCs

For Habitat Projects Only:

Primary Affected Biodiversity Investment Area:

Other Affected Biodiversity Investment Areas:

Problem Statement:

The Duluth-Superior Harbor in Duluth, MN and Superior, WI is contaminated with a number of compounds including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), lead, and mercury (Crane et al, 1997). This harbor has been designated as one of 43 Great Lakes Areas of Concern (AOCs) by the U.S./Canada International Joint Commission's Great Lakes Water Quality Board. Sediments, however, are inherently difficult to remediate and most often dredging is employed. Dredging does not eliminate the problem as some contaminated sediment is resuspended into the water column and the removed sediment must still be treated. An innovative technology that may be appropriate for water quality restoration and long term protection in lieu of dredging or before and after dredging is in situ sediment aeration to develop a remediative cap. This technique improves water quality by increasing the dissolved oxygen (DO) concentration at the sediment-water interface and by reducing sediment and water column oxygen demand. It is hypothesized that the increased dissolved oxygen levels will decrease contaminant flux from the sediment by stimulating biological degradation and limiting sediment resuspension by sediment dwelling worms and other organisms. These effects will improve degraded aquatic and sediment habitat, facilitating recovery of sensitive and native aquatic species. A similar remediation technique (i.e., sidestream elevated pool aeration) has been successfully implemented in the Chicago River and Cal-Sag Channel in Illinois (A.S.C.E., 1994).

The goal of this project is to evaluate and design turbulence and aeration promoters for use as "remediative caps". Use of aeration stations, for example, is one of the recommended management tools proposed by the Corps of Engineers (U.S.A.C.E., page 17, 1997), yet no process evaluation or preliminary design has been performed. Restoration projects at other AOCs may benefit also from this project. Many other AOCs are located in harbors, bays, or river mouths where in situ aeration, or the location of surface pumps may be appropriate. In addition, many of the organic and inorganic contaminants that would be affected by air sparging at each site (i.e., PAHs and ammonia) possess similar physical-chemical properties.

In this project, we will: (1) address under laboratory conditions the effects of water column DO concentration and near-surface turbulence on the fluxes of selected organic and inorganic species across the sediment-water interface, including the measurement of sediment oxygen demand (i.e., DO flux across the sediment-water interface); (2) address in laboratory pilot studies the depth of the aerated zone with respect to aerobic hydrocarbon-degrading bacteria and amphipods and oligochaetes (bioturbators) in the sediment as a function of near surface turbulence conditions and sediment oxygen demand; (3) address, in core sediments taken from the field site, the DO and hydraulic requirements for an effective sediment cap and the effectiveness of the designed field system to develop a remediative cap; and (4) design, through the use of a computational fluid dynamics model, the aeration system required to develop a remediative cap at one field site.

Proposed Work Outcome:

The proposed work will study the effectiveness of using bubblers to create "remediative caps" over contaminated sediments. The project will also include selection (through discussions with GLNPO personnel) of an appropriate site for field tests. Each of these tasks are outlined in more detail below:

Site selection and characterization. Based on hydrology and existing water quality, and in consultations with GLNPO, a site for the field study in the Duluth, MN harbor will be selected. Slip C (Crane, 1999) is one candidate site that is well characterized and has significant hydrocarbon contamination. For a proposed site, hydraulic and hydrologic information will be collected, sediment samples will be obtained, and physico-chemical characteristics of the water column and surficial sediments will be determined. In particular, selected organic constituents will be measured. Roughly 12 to 24 sediment cores will be taken from the selected site for laboratory studies required for the design of an effective near-sediment DO and turbulence enhancement system.

Laboratory Bench-Scale Studies. Studies will be conducted on the sediment cores overlayed with Lake Superior water collected from the field. The primary question to be addressed is what degree of turbulence is sufficient at the sediment-water interface to create an effective remediative sediment cap. This question will be answered by measuring the DO concentration in the sediments under various water column DO and turbulence conditions. In addition, sediment-water fluxes of various PAH's such as pyrene, phenanthrene and fluoranthene, DO, and other constituents will be measured in these studies. The turbulence will be generated by an oscillating grid in the water column with well-documented turbulence characteristics (Valsaraj, et al, 1997). Species will be monitored in the water column and by capturing volatile organics in the off-gas on tenax resin (Jafvert et al., 1995).

Numerical Design of Remediative Cap System. The design of a system to increase turbulence and DO near the sediment-water interface will be undertaken with well-established numerical models (Zic and Stefan, 1991; Patankar, 1980). The size and placement of surface aerators, submerged aerators, surface pumps, etc. will be tested with the numerical model for the chosen field site. These studies will also focus on the costs of implementation and the effectiveness of the remediative cap achieved, based upon the laboratory studies on sediment cores. Optimization requires examining aeration device characteristics and spacing to determine the cost of an effective remediative cap. The depth, stratification dynamics, temperature, etc. of the site will be taken into account during this numerical system optimization.

Design of a Field Remediative System. Once the device and placement have been chosen for the field site, the entire system cost, including operation and maintenance, for developing a sediment remediative cap will be estimated. The purpose of these cost estimates is for decision makers to compare the remediative sediment cap with other options.

Project Milestones:	**Dates:**
Project Start	10/2000
Complete Bench-Scale Studies	09/2001
Publish Year 1 Progress Report	01/2002
Complete Numerical Design of Rem. Cap	06/2002
Complete Design of a Field Rem. System	08/2002
Publish Final Report	09/2002
Project End	10/2002

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☒ Project Addresses Environmental Justice

If So, Description of How:

The environmental sins of the past are contained in the sediments of our harbors. The Duluth-Superior Harbor has been polluted by a variety of activities in the watershed, being one of the busiest commercial ports in the Great Lakes area. Funding this project will provide resources for educational outreach in this region, and provide students at the University of Minnesota exposure to water quality issues in this severely degraded water body.

☒ Project Addresses Education/Outreach

If So, Description of How:

The principal investigators will work with GLNPO, the Minnesota Pollution Control Agency, Watershed Districts and Counties staff in identifying community groups for which workshops or short seminars related to this project can be made. At least two presentations each year will be made at the Saint Anthony Falls Laboratory, University of Minnesota. Funding of this project will provide support towards the completion of degree requirements of two M.S. students in water resources and environmental engineering at the University of Minnesota.

Project Budget:

	Federal Share Requested ($)	Applicant's Share ($)
Personnel:	92,947	51,707
Fringe:	39,736	14,168
Travel:	7,000	0
Equipment:	12,000	0
Supplies:	16,000	0
Contracts:	0	0
Construction:	0	0
Other:	0	0
Total Direct Costs:	167,683	65,875
Indirect Costs:	72,247	38,866
Total:	239,930	104,741
Projected Income:	0	0

Funding by Other Organizations (Names, Amounts, Description of Commitments):

Description of Collaboration/Community Based Support:

As was the case for this proposal, the full proposal will be developed in consultation with Judy Crane and Pat Carey at the Minnesota Pollution Control Agency. Upon request of a full proposal, additional support will be solicited from other sectors. This may include the U.S. Army Corps of Engineers.

References

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